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# A Review of Bond, Beam-Column Joints, and Base Load Transfer in CE-CFST Columns

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**ABSTRACT**

Columns that utilize a concrete-encased concrete-filled steel tube (CE-CFST) are composed of an inner concrete-filled steel tube and an outer reinforced concrete encasement around the inner tube. Although there have been numerous studies on the strength of CE-CFST columns, they are ultimately determined by the detailing at the following locations: (1) the steel tube-to-concrete interface and its bond and slip response; (2) the beam-to-column connections and their force transfer mechanisms; and (3) the column bases and load paths to the foundation. The review of the literature indicates that construction sequence and interface conditions can significantly impact the mobilization of the composite action and the stability of the cyclic response. Studies of beam-to-column connections found that connection configuration controls local deformation and stress concentrations around the steel tube, which ultimately governs energy dissipation, ductility and how much stiffness is retained over time. Furthermore, many researchers concluded that force transfer robustness is more important than peak strength. The available studies on column bases found that there are three different types of load paths and failure points for the following base concepts: (i) exposed; (ii) embedded; and (iii) concrete encased. In addition, there are anchorage and confinement details required for ductile behavior of CE-CFST columns and to avoid premature failure of the concrete encasing and localized distress to the steel tube due to unsupported loading conditions. There were several identified gaps in the research regarding how interface behavior and load conditions at connections and bases apply during repeated lateral loading; how test results can be used consistently in order to share knowledge gained from one study; and how to design according to constructible detailing solutions.

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## 1. INTRODUCTION

This review considers how the following elements affect the practical performance of concrete-filled steel tube (CFST) columns:1) the bond/slip behaviour and steel/concrete interface, 2) detailing of beam-column connections and transfer of load, and 3) column-base detailing and load paths from anchorage. We aim to synthesize findings from experimental studies, design-based literature, and applicable construction and robustness details to assist with forming an accurate evaluation of what composite actions can be achieved for installed structures, as opposed to reproducing strength evaluations used in design documentation. For this reason, this review is limited to analyzing the three areas described above; and with the exception of referencing confinement theory and global model theories for member-level performance, these will not be covered in detail. For all three areas, literature currently available will be evaluated based on specimen configuration, detailing parameters and failure modes so that implications for practice and future research can be identified.

Concrete-encased CFST (CE-CFST) columns are made up of a composite of an inner CFST (concrete-filled steel tube) element with an outer cement-encased RC (reinforced concrete) element. In addition to providing an additional connection interface (steel tube to outer RC) and alternative loading paths (both of which will be examined in this review), CE-CFST contains a significant impact on connection and base detailing, as well as the relationship between connection and base detailing and the loading path of the structural system as a whole because it is designed based on the details involved in the design of a CE-CFST. This means that conventional CFST or encased steel evidence will only be used in this review to clarify the CE-CFST mechanisms and to provide direction for practical CE-CFST designs.

Some major distinctions relative to detailing include the following:

• A further interface (due to the fact that in CE-CFST the steel tube is not the outside surface) that affects the bond/slip/force transfer. There is an effect on the bond/slip/force transfer at the steel tube/outer RC (reinforced concrete) interface.

• The inner CFST may share its axial load, shear and moment with the outer RC jacket, therefore the detail of the joint and the base may have a significant effect on the connection performance of the joint and the overall performance of the connection.

• The overall quality of the interface and the performance of the connection can vary with regard to casting sequence, tolerances and variability in workmanship.

## 2. Review Methodology

This literature review synthesizes the peer-reviewed articles and conference proceedings that pertain to concrete-encased composite steel tubular (CECFST) columns and some relevant literature on concrete-filled composite steel tube (CFST) columns and concrete-encased steel sections that will assist understanding the mechanisms of CECFST. The articles and papers reviewed were found by conducting keyword searches using a combination of the following words: "concrete encased composite steel tube", "CECFST", "bond slip", "concrete-steel interface", "beam column joint", "diaphragm", "blind bolt", "column base", "anchorage", and "foundation connection". The papers screened were preferred according to whether they reported on (i) the physical behaviour (bonding/slip) of the concrete-steel interface and the effect of influencing variables of force transmission from the steel to the concrete; (ii) the detailing of the beam-column joint and the means of force transmission and observed response modes/failure modes; and (iii) the detailing of column base connections, means of anchorage to the foundation, and the load path from the column to the foundation. All the studies selected were qualitatively analyzed according to the above themes; no quantitative analysis or meta-analysis of the data was completed.

## 3. Review of Detailing-Sensitive Mechanisms in CE-CFST Systems

### 3.1 Bond Behaviour between Encased Concrete and Steel Tube.

The interaction between the inner CFST (Concrete-Filled Steel Tube) and outer RC, especially the bond strength, may have an impact on the mechanical characteristics of a composite component made up of an outer concrete and an enclosed CFST. Most studies on the mechanical characteristics of CE-CFST columns emphasize that bond strength and structural integrity are critical factors in predicting the behaviour of steel-concrete columns. This is because they significantly contribute to the ultimate strength of columns [1]. It is essential to assess the contact behaviour between steel and concrete to ensure serviceability, ultimate capacity, and reliability. It has been established through research that the bond strength between the steel tube and core concrete plays a crucial role in facilitating load transfer between the two components. To ensure composite action between the CFST component and the RC component, it is essential to have effective stress transfer between the steel tube and the outer concrete. According to Han and An, 2014 [2], the outer concrete is confined by stirrups, and the core concrete is confined by its steel tube, as shown in Figure (1). In this context, P1 represents the steel tube-core concrete interaction stress, P2 represents the steel tube-outer concrete interaction stress, and P3 represents the stirrup’s confined stress on the outer concrete. While the preceding discussion defines the constituent interactions that form composite action, the key practical implication is that the overall response is highly sensitive to how effectively these interactions are mobilized in real members. In CE-CFST, any reduction or delay in force transfer across the steel–concrete interfaces can weaken the intended confinement chain, promote localized slip and split cracks, and accelerate stiffness/strength degradation—particularly under cyclic demands. Therefore, the following studies are reviewed with emphasis on interface conditions and detailing measures that govern the mobilization of composite action rather than member-level strength models

Much research was conducted to study the bond behaviour of steel tubes and concrete cores in CFST columns [3-6] and the bond performance of concrete encased steel columns [7]. However little research was exit to study the bond behaviour between the inner CFST and outer RC for concrete-encased CFST columns [8].

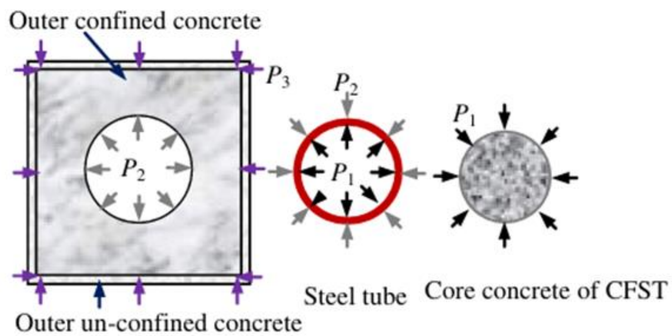

Figure (1): Interaction model between steel and concrete [2].

The comparison of bond stress versus slip relation between circular concrete-filled steel tube columns CFST [9] and concrete-encased CFST columns CE-CFST [8] as shown in Figure (2). It can be observed that the concrete-encased CFST column has a bond strength that is approximately three times greater than the CFST column. It indicates that the composite action of the inner CFST and the outer RC can be effectively achieved without the need for additional shear connectors. Furthermore, it is noteworthy that the bond stress versus slip relationships of the CFST column are smooth while the concrete-encased CFST column exhibits dramatic fluctuations.

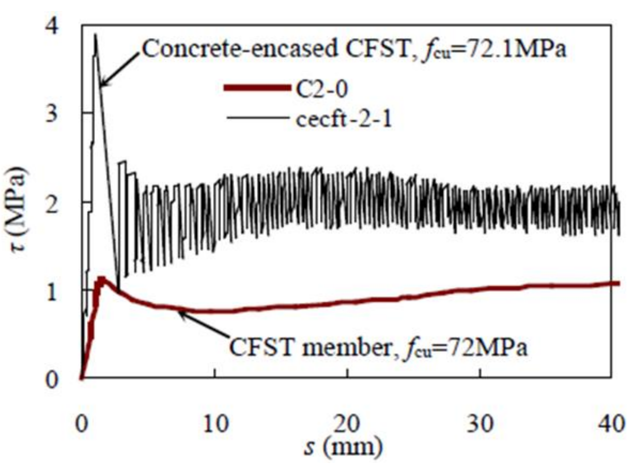

Figure (2): Bond stress (τ) versus slip (s) relationships [8].

Shen et al. (2025) [10] conducted push-out tests on CE-CFST specimens and applied acoustic emission (AE) monitoring to characterize the bonding failure and interfacial damage evolution between the CFST tube and the surrounding outer concrete. Using AE energy and cumulative AE energy as damage indicators, they showed that AE parameters can effectively track the progression of interface deterioration during loading. Based on the AE energy characteristics, they further proposed stage-based descriptions of bond degradation: for circular steel tubes the process followed adhesive -local slip - slip, whereas for square tubes an additional friction stage appeared (adhesive - local slip -friction - slip), indicating that tube geometry influences the damage evolution pattern.

### 3.2 Beam–Column Joint Detailing and Force Transfer

The structures are designed to safely resist vertical and lateral loads throughout their service life. The connection zone between the column and beam is one of the most critical regions in various structures, including bridges, industrial structures, buildings, underground subways, and stadiums. According to Li et al., 2018a [11], the consistency of the structure is influenced by the behaviour of the column-beam connection. To achieve the desired structural design, various column-beam connection types can be applied, such as moment resisting (rigid joint), semi-rigid, shear, or truss connection. These connections should demonstrate sufficient adaptation against axial and shear forces, bending moments, ductility, rigidity, different settlements, thermal expansion, and long-term vibrations.

The concrete-encased CFST columns can be connected with either steel or reinforced concrete (RC) beams in buildings for fast construction and robust structural systems. Figure (3) a and b show the concrete-encased CFST column to steel beam joint and RC beam joint in real buildings, respectively. The details of the column-beam connection should ensure the efficiency of transmitting the load between the embedded CFST component and beams, which is essential for these composite joints.

Many researchers conducted various types of connections between CE-CFST columns and RC or steel beams. Wang et al., 2020 [13] and Wang et al., 2021 [14] introduced blind bolts connection between the steel beam and concrete-encased CFST column, see Figure (4). The results declared that this novel connection provided favourable structural behaviour.

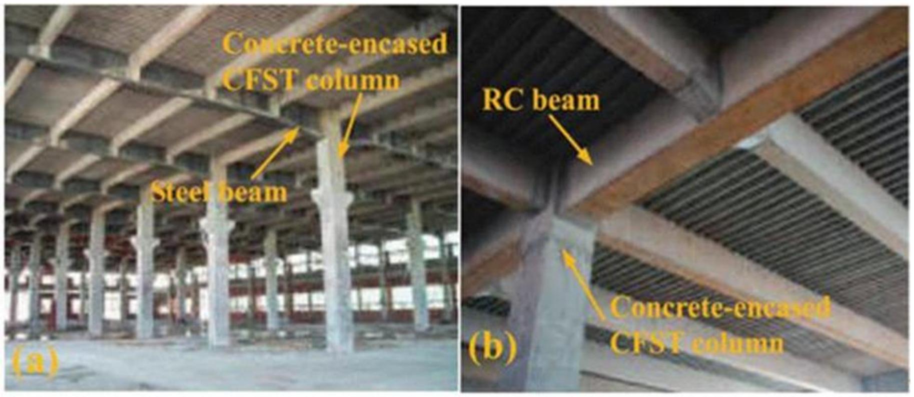


Figure (3): CE-CFST columns to beam joint; (a) columns to steel beam connection; (b) columns to RC beam connection [12].

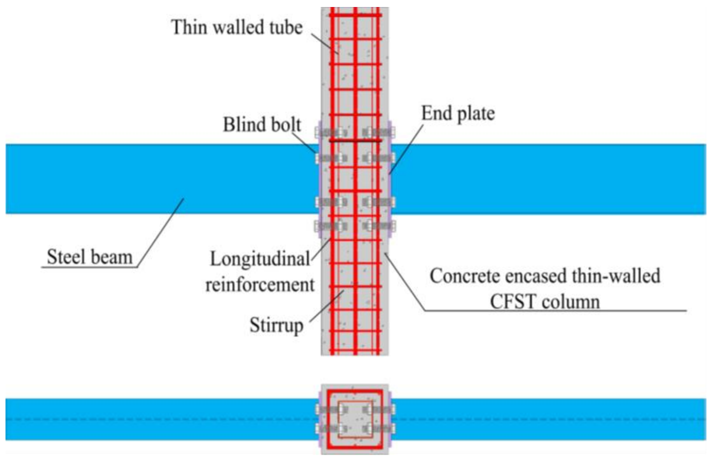


Figure (4): Typical blind bolted connections to CETCFST columns [13].

Li et al., 2020 [15] studied nine varied composite connection details for the steel beam to concrete-encased CFST column, as shown in Figure (5). These studies involved applying constant axial compression on the column and reverse cyclic loading on the beam end. The study found that the connection details significantly impacted the stiffness, joint strength, ductility, and energy dissipation capacity. The joints with external diaphragms and through-beams demonstrated the most favourable cyclic performance due to their enhancement of the load transfer mechanism and reduction of localized deformation and stress concentration around the steel tube. However, since this study was based on laboratory cyclic tests conducted at a fixed axial load level, additional research needs to be done concerning the sensitivity of the axial load applied to these joints and how practical construction details can be achieved for these joints in actual buildings.

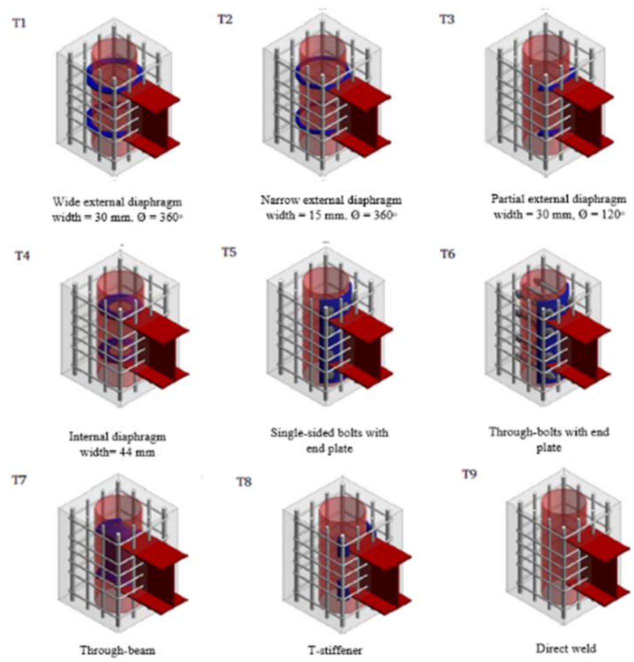


Figure (5): the nine composite connections between the CE_CFST column and beam [15].

Liao et al., 2014 [16] studied composite joints between the concrete-encased CFST column to RC beam joints and steel beam joints with and without slabs, see Figure (6). According to the study, the presence of an RC slab could substantially improve the beam strength, leading to a shift in the joint failure mode from beam failure to joint or column failure mode.

To achieve the continuity of the concrete-encased CFST columns, both the steel tube and the rebars in the column must extend through the joint area. Ma et al., 2019 [17] and Ma et al., 2020 [18] introduced many types of composite joints (ring plate connection, sleeve connection, wing plate connection, and anchorage connection) between the encased concrete-CFST and RC beam, as depicted in Figure (7). The results of the study showed the four types of connections remained intact and provided an effective connection.

For all the types of joints reviewed, the behaviour of the joint will depend primarily on the means of transferring forces from the beams into the CE-CFST columns via continuous and reliable load paths (connections). The detailing of connections with steel beams (e.g. blind-bolt systems, through-beams, and external diaphragms) is intended to: (i) distribute the forces applied to beam flanges, (ii) minimize stress at the steel tube/column interface, and (iii) limit deformation of the steel tube locally; all of these three features together improve the retention of stiffness and energy dissipation under cyclic loading. For the connections between RC and steel beams (e.g. sleeve, ring/wing plates, and anchorage-type details), performance will be dictated by the anchorage of the longitudinal reinforcement, the integrity of the joint core, and the ability to avoid premature degradation of bond and cracking in the vicinity of the joint, which would otherwise interfere with the force transfer. Overall, joint behaviour is characterized as either "beam-governed" or "joint/connection-governed" based on whether the connection detailing facilitates ductile yielding away from the face of the column or causes early local joint damage (e.g. concrete crushing, interface slip or connector failure). These findings suggest that joint detailing for CE-CFST should be assessed in terms of not only peak strength, but also the robustness of the load-transfer capacities, compatibility of deformation, and extent of damage localization of the joint, particularly under cyclic loading.

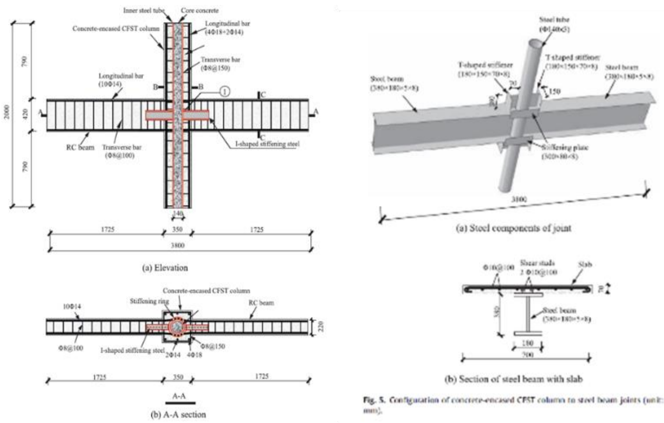


Figure (6): Configuration of concrete-encased CFST column to RC and steel beam joints [16].

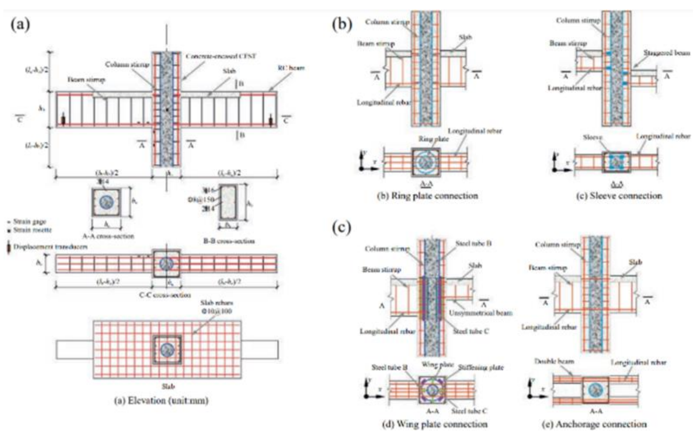


Figure (7): Configuration of joint specimens [17].

**3.3 Column Base Detailing and Foundation Load Transfer**

The column-to-foundation connection also known as a column base, is the critical structural component to consider when the design of the CE-CFST structure. It must be stiff and strong enough to transfer loads from the superstructure. Strength and stiffness are crucial properties for column bases when using CFST columns [19]. Therefore, it is of great importance to design the column bases with adequate stiffness, strength, as well as energy dissipation capacity. It has been summarized that engineering techniques often use one of three types of column bases: exposed base-plate connection, embedded connection, and concrete-encased connection, as shown in Figure (8). The column base connection can be broadly categorized into three concepts: exposed base-plate, embedded, and concrete-encased bases. In exposed base-plate systems, the column is connected to the foundation through a base plate and anchor rods, and the rotational response is influenced by base-plate flexibility and anchorage layout.

The embedding of the column in the foundation allows the base of the column to develop its strength and stiffness by utilizing the bearing and bond developed over the length of the embedment. In this way, the rotation of the embedded base about its base plate is reduced. The concrete-encased base is considered to be an improvement of the base-plate design, where an RC encasement adds an additional confined area around the column end and an alternative load path around the steel tube.

Xu et al. (2016) [20] provided, through experimental investigation, a direct, experimental evaluation of the behaviour exhibited by concrete-encased CFST column bases when subject to both (constant) axial loading and (cyclic) lateral loading. From the research carried out, it was concluded that the base response and deformation capacity were ultimately a function of (a) the load path used and (b) the detailing of the anchoring/confinement system in the base region, with a clear relationship showing that column bases using different detailing had different failure modes. Furthermore, it was noted that, in order to achieve ductile (cyclic) behaviour, it is essential to prevent premature splitting of concrete around the anchored system, and limit the extent of local damage adjacent to the steel tube/base interface which would allow the inelastic demand to continue without the immediate loss of strength. Additionally, the literature dealing with column bases of steel/composite materials (see [21] [19]) indicates that base plate flexibility/anchorage layout/localised concrete bearing/splitting has a significant impact on both the rotation capacity and the location of damage in the column base.

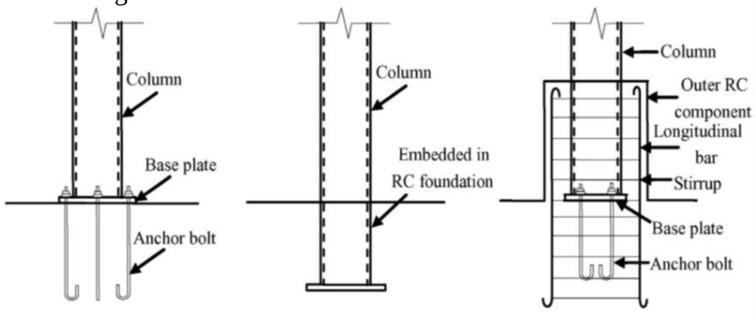


Figure (8): Schematic view of three types of column bases.

The above three basic concepts give different load transfer paths and consequently also different vulnerability locations from a force-transfer perspective. For exposed base-plate systems, most of the axial load and overturning moment transfer through the base plate, the anchor rods, and the concrete bearing, putting these systems' response at risk of failure from changes in anchor layout, base-plate flexibility, or local concrete crushing/splitting. Embedded bases create resistance through the bearing and bonding along the length of the embedment, generally causing an increase in the initial stiffness, but can potentially create a change in the demand for damage to the adjacent concrete area. Concrete- encased base details will also provide an additional load transfer path in addition to the RC outer jacket around the steel tube, thus providing a solution that may stabilize the cyclic response of the column if adequate anchorage and transverse reinforcement exist to prevent premature splitting or local damage. Therefore, the performance of column-base connections should be evaluated not only for ultimate strength but also for deformation capacity, areas of damage concentration, and detailing constraints associated with constructability.

## 4. Research Gaps and Future Work

The composite action and hysteretic response of CE-CFST systems are contingent upon level of detailing in the construct. Bond-slip performance at the interface of CE-CFST systems is influenced by surface finish, confinement, and construction sequencing; however, there is little consistency amongst the different bond models to establish a design-ready bond model considering long-term effects of shrinkage/creep and degradation due to repetitive loading conditions at the interface. In the context of beam-column connections, it has been demonstrated by some studies that diaphragm or blind-bolted solutions provide satisfactory performance; however, comparisons across different studies have presented challenges due to variations in specimen geometry and loading histories. For column base connections, it was found that the loading path definition (base-plate, embedded or concrete-encased type) strongly influences the performance of the base connection; moreover, there have been sufficient findings that energy dissipation/ductility can be achieved at the column base connection provided that the anchor and confinement details adequately prevent premature failure of the concrete due to splitting or distress of the steel tube. The following key research gaps within the CE-CFST literature warrant further investigation: (i) establishment of a greater level of standardization in the reporting of test configurations and boundary conditions for the interface and connection tests that would allow more direct comparisons between tests; (ii) linking between the bond performance at the interface and the connection demands for repetitive lateral loading; (iii) create scalable detailing guidance for cyclic/lateral load applications (joint/base) that facilitates constructability whilst balancing performance; (iv) validation of the construction details used in the field, including dimensional tolerances, workmanship variability and reparability.

## 5. Conclusions

• The repeated identification in researched articles of bond strength and integrity of bonding interface as significant measures of successful operation and total capacity of CECFST columns is shown to govern stress transfer between the inner composite fiberglass and the outer reinforced concrete jacket which are being bonded together.

• An important aspect to ensure strong composite action is the presence of the load transfer between the steel tube and the concrete. Therefore, it is vital to determine the behaviour of the contact interface between the steel and concrete for serviceability, ultimate capacity and reliability.

• The papers reviewed concerning the confinement mechanism referenced in the literature provided sufficient evidence to understand how the outer concrete is confined by the stirrups, while the core concrete is confined by the steel tube. Therefore, the interface interaction between the steel tube and both types of concrete can be defined as the three stresses acting together (P1: tube to core concrete, P2: tube to outer concrete, and P3: stirrup confinement to outer concrete).

• Specific investigations of the bond–slip behaviour of combined-concretes and standard-concretes reveal that there is much higher resistance to bond for the combined concrete–concrete (CE) members. This supports the premise that composite actions between the interior member and the CM beam member can be successfully achieved. Some studies also report that some cases exist in which no additional shear connectors are required to accomplish this goal.

• The connection area between the beam and the column (panels) is repeatedly mentioned as being, by far, the most important portion of any structure in terms of how well it will react to lateral loads during seismic events. Therefore, detailing of the joints must allow for the efficient transfer of loads from the beams to the interior combined concrete beam that has been embedded in the column.

• The reviewed literature reports multiple joint concepts connecting CE-CFST columns to steel or RC beams, including blind-bolted details and composite connection arrangements, with reported favourable structural behaviour for the proposed blind-bolt concept.

• Results reported for a range of composite joint details show that connection configuration significantly influences joint stiffness, strength, ductility and energy dissipation; details using external diaphragms and through-beams are reported to provide favourable cyclic performance by enhancing load transfer and reducing localized deformation/stress concentration around the steel tube.

• Additional reported observations indicate that the presence of an RC slab can increase beam strength and may shift the governing failure mode from beam failure toward joint/column-related failure, which should be considered in joint detailing decisions.

• Continuity requirements are emphasized in the reviewed studies, where both the steel tube and longitudinal reinforcement are recommended to pass through the joint region; several reported joint types (ring plate, sleeve, wing plate, and anchorage connections) remained intact and provided effective connection behaviour in the cited experiments.

• The column base (column-to-foundation connection) is identified as a critical component for CE-CFST systems because it must provide sufficient stiffness and strength to transfer forces from the superstructure to the foundation.

• The existing literature categorizes the column connection/base plate solutions into three groups: exposed base plate connections, embedded connections, and concrete encased connections. Each grouping has an alternate method of anchoring and transferring loads.

• For embedded base plate systems, as per literature, strength and rigidity are generated by embedding the column deep into the foundation and this alters the column's rotational and load transfer behaviour as compared to exposed base plate system connection configurations.

• Experimental results from testing of CE-CFST concrete encased column connection systems demonstrated that they have excellent strengths, ductility and energy-absorption capabilities, but may be somewhat more complicated to build than other connection types at the base plate levels.

## REFERENCES

[1] N. Li, Yiyan, Shan, L., & D, Gao. Axial compressive behaviour of steel fiber reinforced self-stressing and self- compacting concrete-filled steel tube columns, 222 (2020).

[2] Han, L. H., & Yu Feng, A. Performance of concrete-encased CFST stub columns under axial compression. Journal of Constructional Steel Research, 93 62–76. (2014). Elsevier Ltd.

[3] Aly, T., Elchalakani, M., Thayalan, P., & Patnaikuni, I. Incremental collapse threshold for pushout resistance of circular concrete filled steel tubular columns. Journal of Constructional Steel Research, 66(1), 11-18.

[4] Tao, Z., Song, T. Y., Uy, B., & Han, L. H. Bond behavior in concrete-filled steel tubes. Journal of Constructional Steel Research, 120, 81-93. (2016).

[5] Guan, M., Lai, Z., Xiao, Q., Du, H., & Zhang, K. Bond behavior of concrete-filled steel tube columns using manufactured sand (MS-CFT). Engineering Structures, 187, 199-208 (2019).

[6] Alemayehu, R. W., Bae, J., Ju, Y. K., & Park, M. J. Bond Behavior of Concrete-Filled Steel Tube Mega Columns with Different Connectors. Materials 2022, 15, 2791.

[7] Wang, X., Liu, Y., Yang, F., Lu, Y., & Li, X. Effect of concrete cover on the bond-slip behavior between steel section and concrete in SRC structures. Construction and Building Materials, 229, 116855. (2019).

[8] Han LH, Wang ZB, Xu W, Tao Z. Behavior of Concrete-Encased CFST Members under Axial Tension [J]. Journal of Structural Engineering 2016;142(2).

[9] Tao Z, Han LH, Uy B, Chen X. Post-fire bond between steel tube and concrete in concrete-filled steel tubular columns [J]. Journal of Constructional Steel Research 2011;67(3):360-378.

[10] Li BY, Yang YL, Chen YF, et al. Behavior of connections between square CFST columns and H-section steel beams. Journal of Constructional Steel Research 145: 10–27. (2018)

[11] Wang, W., Wang, J., Guo, L., Guo, X., & Liu, X.. Behavior and analytical investigation of assembled connection between steel beam and concrete encased CFST column. In Structures (Vol. 24, pp. 562-579). Elsevier (2020).

[12] Yu Feng, A., Hai Han, L., & Ling Zhao, X. Experimental Behaviour of Box concrete-encased CFST eccentrically loaded column. Magazine of Concrete Research, 65(20), 1219–1235 (2013).

[13] Wang, W., Wang, J., Guo, L., Guo, X., & Liu, X. Behavior and analytical investigation of assembled connection between steel beam and concrete encased CFST column. Structures, 24 (2019),562–579.

[14] Wang, J., Hu, Z., Guo, L., Wang, B., & Yang, Y. Analytical performance and design of CECFST column assembled to PEC beam joint. KSCE Journal of Civil Engineering, 25, 2567-2586. (2021).

[15] Li, W., Xu, L. F., & Qian, W. W. Seismic performance of concrete-encased CFST column to steel beam joints with different connection details. Engineering Structures, 204, 109875 (2020).

[16] Liao, F. Y., Han, L. H., & Tao, Z. Behaviour of composite joints with concrete encased CFST columns under cyclic loading: Experiments. Engineering Structures, 59, 745-764 (2014).

[17] Ma, D. Y., Han, L. H., & Zhao, X. L. Seismic performance of the concrete-encased CFST column to RC beam joint: Experiment. Journal of Constructional Steel Research, 154, 134-148. (2019)

[18] Ma, D. Y., Han, L. H., Zhao, X. L., & Yang, W. B. Seismic performance of the concrete-encased CFST column to RC beam joints: Analytical study. Steel and Composite Structures, 36(5), 533-551 (2020).

[19] Han, L. H., Hou, C. C., & Xu, W. Seismic performance of concrete-encased column base for hexagonal concrete-filled steel tube: numerical study. Journal of Constructional Steel Research, 149, 225-238 (2018).

[20] Xu, W., Han, L. H., & Li, W. Seismic performance of concrete-encased column base for hexagonal concrete-filled steel tube: experimental study. Journal of Constructional Steel Research, 121, 352-369. (2016).

[21] Nakashima, M., Inoue, K., & Tada, M. Classification of damage to steel buildings observed in the 1995 Hyogoken-Nanbu earthquake. Engineering Structures, 20(4-6), 271-281(1998).

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